EFFECT OF EXCESS AIR ON EMISSION LEVEL AND ENERGY CONSUMPTION OF L.D.O. FIRED ROTARY FURNACE

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Abstract:

The large amount of flue gases produced by cast iron foundries using Coke fired cupolas for melting ,contains injurious elements like SO_2, CO_2, CO, H_2 S, NOx, SPM etc. which damages the environment and are dangerous to all living beings. The emissions level of above have not been found within the pollution control limit as set down by Central Pollution Control Board of India.

Energy consumption is another major problem being faced by the Indian ferrous foundries "Bureau of Energy Efficiency, and "The Energy Research Institute,"Govt of India New Delhi & other International agencies reported that energy consumption in Indian ferrous foundries is much more above the required limits and has to be drastically reduced.

The authors conducted a series of experimental investigations on the L.D.O. fired rotary furnace installed at foundries of Agra and investigated the effect of excess air on Emission level and Energy consumption of Furnace. The experimental investigations revealed that by reducing excess air, not only the emission levels and energy consumption were drastically reduced but the performance of furnace was also considerably improved.

***Key Words** – Rotary furnace, Emission level, Energy consumption Excess Air,*

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1. Introduction[1],[2]:

The Rotary Furnace is very simple melting unit consisting mainly of a drum of required size having a cone on each side lined with refractory, fire bricks or ramming mortar generally having alumina as a constituent. This drum is placed on rollers so that they may be either locked or slowly rotated about their central axis. The rollers are driven by a small electric motor. At one end of the drum, a suitable burner using the Light Diesel Oil (L.D.O.).is placed with appropriate blower system and combustion gases exit from other end. Two conical portions on both sides flank this drum or horizontal cylinder. One of the cones accommodate the burner whereas from the other cone hot flue gasses exit. Charging of the iron for melting is also done from this side. The tap hole is located in the cylindrical wall halfway between the ends. This tap hole is used to take out the molten metal but it is kept closed during the melting of metal. The air is supplied through blower system for complete combustion of light diesel oil. It was observed that if this air is in excess the emission levels and energy consumption increased. The main purpose of investigation is to select the optimal percentage of excess air for optimum emission levels and energy consumption.

2. MATERIALS AND METHODS:

2.1 Experimental setup and data collection[3]--The experiments have been conducted on self designed and developed200 kg rotary furnace, installed at foundry division of M/S Harbhajan Singh Namdhari Enterprises, Industrial Estate, Nunihai, AGRA(U.P.) INDIA as shown in Figure 1

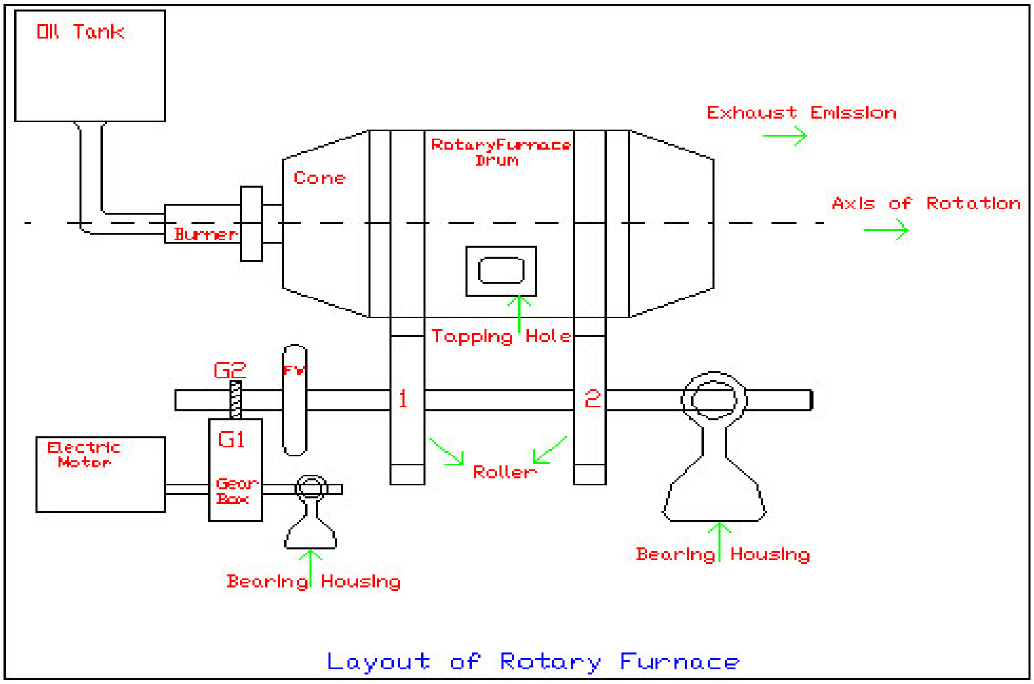

Fig.1. Designed and Developed Rotary Furnace

In the experimentation, 200 kg of the charge is melted in the rotary furnace. A Circular burner is used for burning Light Diesel Oil (L.D.O.) as fuel. By rotation, the major heat transfer takes place by radiation. Some heat transfer takes place by conduction when charge meets heated refractory, and part of it by convection, in initial stages. Initially furnace starts from room temperature, therefore more fuel, energy is consumed in first heat, and for later heats, the fuel and energy consumption is reduced. Numbers of experiments were conducted for optimizing excess air consumption and the observations specific fuel and energy consumed in melting, were recorded.

2.2.Excess air:- Minimum amount of air, which is required for complete combustion of fuel, is calculated theoretically, but always excess air is used because whole of the air supplied for combustion purpose does not come in contact with the fuel completely and as such a portion of fuel may be left unburnt. Therefore, an additional amount of air is required to be supplied for complete combustion of fuel. This additional amount of air is known as excess air. For optimum emission level of pollutants and energy requirement, the optimal excess air should be supplied and the exhaust gases from the furnace can preheat it.

2.3.Experimental investigation(1) - Effect of excess air on emission levels, and, energy consumption when furnace operated under existing conditions of operation-[4]- —The furnace was operated at 2.0 rpm, as per existing conditions of operation. The charge per heat is 200.0 kg. In first heat, as furnace was started from room temperature, more air was required, the melting time, emission level of pollutants, fuel and energy consumption were more. In subsequent heats, the air was reduced, subsequently the melting time, emission level of pollutants , fuel and energy consumption were also reduced. Under existing conditions the excess air varied from 1300.5m^3 to 1174.0 m^3 that amounts approx. to 30%.1liter of LDO is equivalent to 9.9047kwh/kg of energy. Observations for emission levels (mg/m3), as measured by neck tell gas analyzer and energy consumption kwh/kg taken during experiments are given in table1 and table 2 respectively-

	Emission levels-mg/m^3			
Heat no.	SOx	SPM	CO_2	CO

SN	Heat no	Rpm	Time min	Fuel liters	Specific Fuel (lit/kg)	Melting Rate (kg/hr)	Excess air m^3	**Excess air %**	Flame temp.^{0}C	**Energy consumption kwh/kg**
1	1	2.0	50.0	92.0	0.460	240.0	1320.0	**30.45**	1310.0	**4.556**
2	2	2.0	47.0	90.0	0.450	255.3	1290.0	**30.41**	1314.0	**4.457**
3	3	2.0	46.0	87.0	0.435	260.8	1240.0	**30.24**	1325.0	**4.308**
4	4	2.0	46.0	86.0	0.430	266.0	1220.0	**30.10**	1334.0	**4.259**
5	5	2.0	45.0	83.0	0.415	266.0	1175.0	**30.04**	1350.0	**4.110**

Table1-Energy consumption of furnace under existing conditions of operations

1	90.0	40.0	4.0	4.0
2	90.0	40.0	4.0	4.0
3	90.0	40.0	4.0	4.0
4	90.0	40.0	4.0	4.0
5	90.0	40.0	4.0	4.0

Table2-Emission level of furnace under existing conditions of operations

2.3.1Effect of excess air on energy consumption and emission level of furnace [4]—

The role of excess air is more dominating as explained in the following sections—

(1)When burners are adjusted to operate with an excess of combustion air, the products of incompletely burnt hydrocarbon fuels- sulphur di oxide, suspended particulate matters, carbon di oxide, and carbon monoxide are minimized but appreciable amount of residual oxygen remains. The combustion volume increases, which increases the energy consumption. Subsequently the emission levels are also increased

(2)But contrary to it when burners are operated with deficient amount of combustion air, all available oxygen is consumed before complete combustion of the fuel, consequently considerable amount of unburnt oxides of sulphur suspended particulate matters, carbon di and carbon monoxide remains which increases the emission levels. The volume of air required for different percentage of excess air for combustion of 1 liter of L.D.O. is given in table 3

S.n	Excess Air percentage	Volume of air required at STP
1	0	10.874 m^3
2	10	11.961 m^3
4	20	13.049 m^3

5	30	14.136 m^3
6	40	15.224 m^3
7	50	16.311 m^3
8	60	17.399 m^3
9	70	18.486 m^3

Table 3 Excess air percentage in m^3 of air

2.3 Experimental investigation (2)-Effect of reducing excess air on emission levels, specific fuel, and energy consumption[4]-Again experiments were repeated by reducing excess air from earlier 30%,. It was reduced gradually in steps of 2-3%.Several sets of observations were recorded. The significant effect was observed for excess air of 20%, with compact heat exchanger, rotating furnace at optimal rotational speed 1.0 rpm, preheating LDO up to 70.0^0C. The observations taken during experiment are given in table 4 and graphical representation is shown in fig 2

Heat no	Flame Temp °C	Rpm	Time min.	Fuel liters	Melting rate (kg/hr)	Specific fuel cons liter/kg	Preheated excess air cons.m^3	Preheated excess air %	Preheated excess air temp.°C	Energy consumption kwh/kg
1	1510.0	1.0	41.0	72.0	293.0	0.360	995.0	30.1	304.0	3.565
2	1530.0	1.0	40.0	70.0	300.0	0.350	970.0	25.5	316.0	3.466
3	1540.0	1.0	39.0	69.0	307.6	0.345	930.0	20.3	320.0	3.417
4	1545.0	1.0	38.0	68.0	315.7	0.340	905.0	20.1	329.0	3.367

5	1550.0	1.0	37.0	66.0	324,3	0.330	870.0	20.2	332.0	3.268
6	1568.0	1.0	37.0	64.0	324.3	0.320	835.0	19.9	340.0	3.169
7	1570.0	1.0	36.0	63.0	333.3	0.315	822.0	20.0	348.0	3.119
8	1578.0	1.0	35.0	61.0	342.8	0.305	795.0	19.9	370.0	3.020
9	1580.0	1.0	34.0	60.0	352.9	0.300	788.0	20.1	378.0	2.971
10	1590.0	1.0	34.0	59.0	352.9	0.295	785.0	20.0	385.0	2.921
11	1620.0	1.0	33.0	58.0	363.6	0.290	760.0	20.0	402.0	2.872

Table 4 Effect of 20.0% excess air on energy consumption

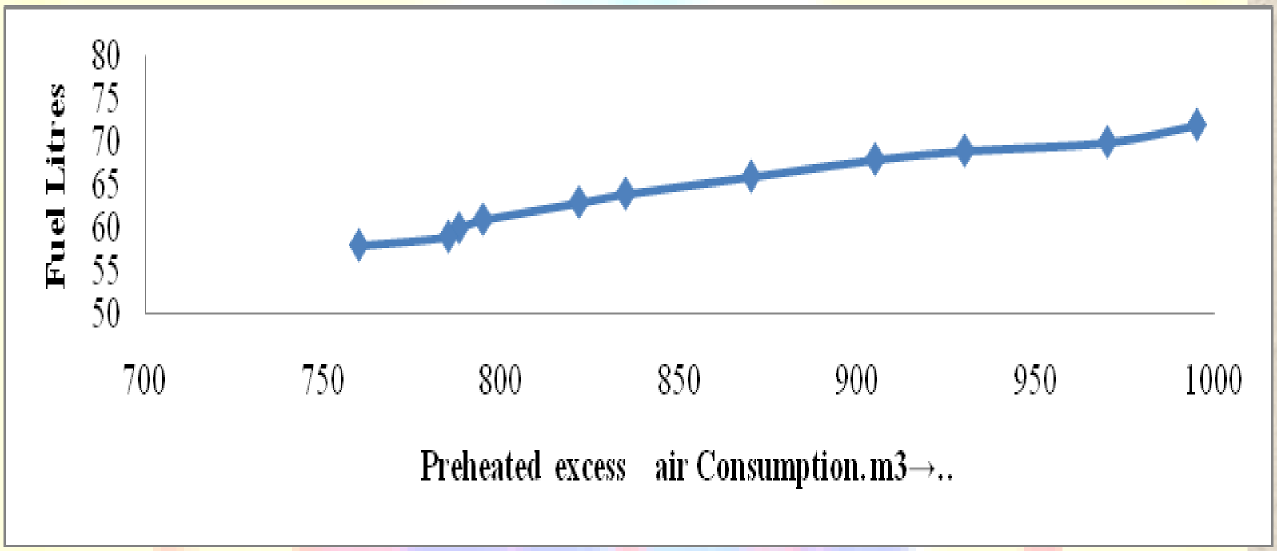

Fig.2 -Effect of reducing excess air to 20% on fuel consumptions

2.3 Experimental investigation (3)- Effect of further reducing excess air on emission levels, specific fuel, and energy consumption-Again experiments were repeated by further reducing excess air from 20%. It was reduced gradually in steps of 2-3%. Several sets of observations were recorded. The significant effect was observed for excess air of 10%, with same compact heat exchanger, under similar conditions. The observations taken during experiment for specific fuel and energy consumption are given in table 5 with graphical representation in fig 3., Emission levels were measured using neck tell gas analyzer for heat no 5,6,and 7 and are given in table 6

S. n	Flame Temp ^{0}C.	Rpm	Time min.	Fuel liters	Melting rate kg/hr	Specific fuel cons. liter/kg	Preheated air (m^3)	Preheated air%	Preheated air temp. ^{0}c	Energy consumption. kwh/kg
1	1644.0	1.0	34.0	59.0	352.9	0.295	810.0	11.4	384.0	2.921
2	1656.0	1.0	33.0	58.0	370.0	0.290	790.0	11.3	392 .0	2.872
3	1666.0	1.0	33.0	58.0	373.0	0.290	755.0	10,0	396.0	2.872
4	1678.0	1.0	32.5	57.0	378.0	0.285	725.0	10.6	398.0	2.822
5	1684.0	1.0	32.0	57.0	382.0	0.285	690.0	10.1	405.0	2.822
6	1693.0	1.0	32.0	56.0	375.0	0.280	680.0	10.1	407.0	2.773
7	1707.0	1.0	31.0	56.0	387.0	0.280	670.0	10.0	412.0	2.773

Table 5- Effect of 10.0% excess air on energy consumption

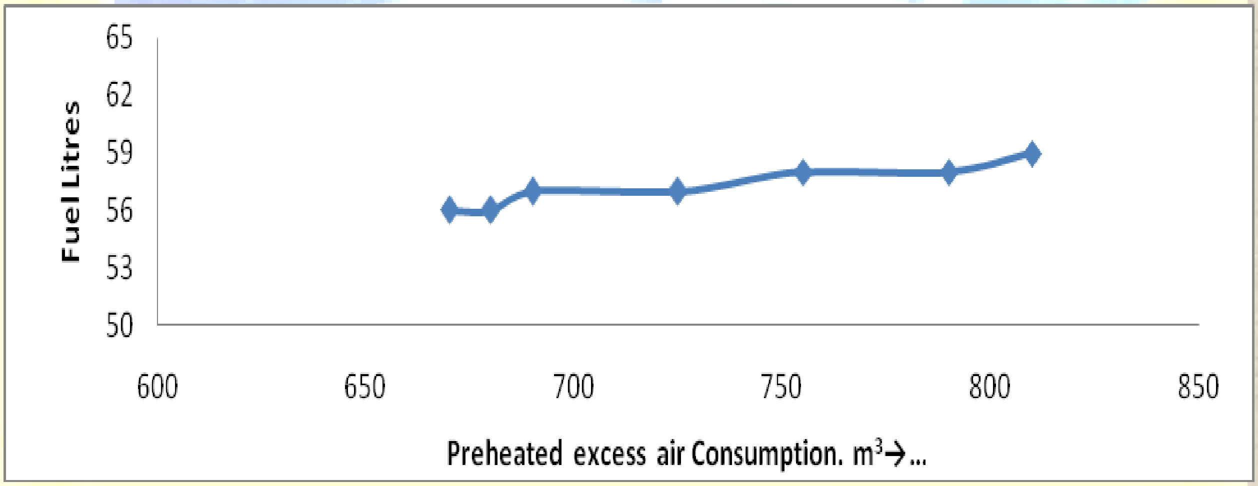

Fig 3- Effect of reducing excess air to 10% on fuel consumptions

Sn	Heat no	Rpm	SO_X	SPM	CO_2	CO
1	5	1	88.0	35.0	3.9	3.9

2	6	1	88.0	35.0	3.9	3.9
3	7	1	88.0	35.0	3.9	3.9

Table 6- Effect of reducing excess air to 10% on emission level of furnace

3.Results-(i) Effect of reducing excess air on performance and energy consumption of furnace-The effect of reducing excess air from 30%,(as operated(under existing conditions of operation) initially to 20.0%, and then to 10.0%, on performance and energy consumption of furnace is shown in table7.

sn	Parameters	Operating furnace with 30.0% excess air	Operating furnace with 20.0% excess air	Operating furnace with 10.0% excess air	Percentage gain
1	Flametemperature ^{0}C	1350.	1620.0	1707.0	+26.44%
2	Melting rate kg/hr.	266.0	363.6	387.0	+45.48%
3	Melting time minutes	45.00	33.00	31.00	+45.16%
4	Fuel Liters/tone	415.0	290	280	+48.21%
5	Specific fuel (lit/kg)	0.415	0.290	0.280	+48.21%
6	Specific energy(kwh/kg	4.110	2.872	2.773	+48.21%

Table7-Effect of reducing excess air on performance and energy consumption of furnace

(ii) **Effect of reducing excess air on emission levels of furnace-** the effect of reducing excess air to 10.0%, on emission levels (mg/m^3) of furnace is shown in table 8

S N	Parameter	Operating furnace with 30% excess air	Operating Furnace with 10.0% excess air	% Reduction in emission levels
1	SO_X	90.0	88.0	2.22%
2	SPM	40.0	35.0	12.5%
3	CO_2	4.0	3.9	2.5%
4	CO	4.0	3.9	2.5%

Table 8 **Effect of reducing excess air from 20 to 10% on emission level**

(iii) Comparison of emission levels on reducing excess air with CPCB limits- the above emission levels have been compared with limits of **CPCB** (central pollution control board) of India (mg/m^3) and given in table 9

Sn	Emission level	CPCB Limits	Rotary furnace	% lower than CPCB limits
1	SPM<3MT	450.0	35.0	92.2%
2	SO_2	120.0	88.0	26.6%
3	CO	5. 0	3.9	22%
4	CO_2	4.0	3.9	22%

Table 9 Comparison of emission levels on reducing excess air with CPCB limits

4. Discussions:

When operated with 30 % excess air the energy consumption is 4.110 kwh/kg and emission levels of SOX, SPM, CO2 and CO were 90.0, 40.0, 4.0, and 4.0 mg/m^3 respectively. Same furnace when operated with 20% excess air, the energy consumption reduced to 2.872kwh/kg and further reducing excess air to10% the energy consumption reduced to 2.773 kwh/kg. The percentage energy reduction is 48.21%

The emission levels also reduced to 88.0, 35.0,3.9 and 3.9 mg/m^3 respectively. These emission levels are 92.2%, 26.6%, 22% and 22% respectively lower than limits of CPCB (Central Pollution Control Board of India).

5. Conclusion:

Several castings have been produced using the L.D.O. fired rotary furnace and the effect of excess air on emission levels and energy consumption, with different percentage of excess air has been studied. It has been found that for optimum emission levels and energy consumption the optimal excess air is 10%.

Reducing excess air reduces the combustion volume which ultimately not only drastically reduced the fuel consumption and emission levels (below CPCB norms) but also significantly increased the melting rate and quality of castings produced

6. Acknowledgement:

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7. Reference list:

- Jain R. K., Singh R, Gupta B.D "Energy considerations in Indian ferrous foundries-an overview'" Indian foundry journal, Vol54, No.8, August 2008, p.p. 32-34.
- Jain R.K., Singh R, "Modeling and optimization of rotary furnace parameters using Regression & Numerical Techniques" 68th world Foundry Congress, Feb 7-10, 2008, Chennai.
- Jain R.K., Gupta B.D. "Effect of flame temperature of LDO fired rotary furnace on fuel consumption, melting time and melting rate." Indian Foundry Journal ,Vol 56, No 11 pp 30-34 November 2010
- Jain R.K., Gupta B,D, Singh R, "Effect of oxygen enrichment& reducing combustion volume on energy consumption emission level, and performance of LDO fired Rotary Furnace" Indian Foundry Journal Vol. , no 12 pp 30-34 December 2009